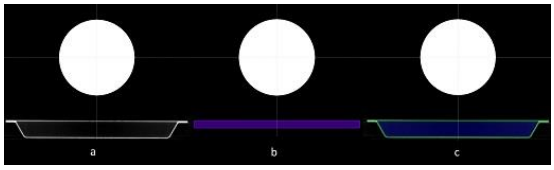
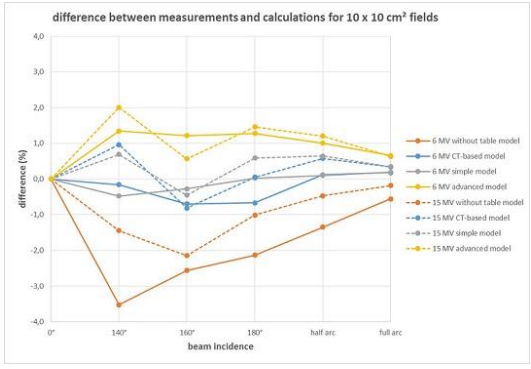


Results

The percentage difference between measurements and calculations in the centre (at isocentre) of the Delta4 phantom is shown in fig 2 for 10 x 10 cm² field configurations both for 6 MV and 15 MV. Graphs for the other investigated field sizes are similar. The percentage differences for the CT-based and simple model are fluctuating around zero, whereas the percentage differences without table and with the advanced table model are all either negative or positive and have a larger range. This means that the CT-based and simple table model are equivalent to each other and superior to the others. Gamma analysis of the prostate plans shows little variances between the different models. This can be declared by the observation in fig 2 that the differences between measurements and calculations are below 1% for full arcs.



Conclusion

The quality of the simple model and the CT-based model are equivalent. It is surprising that the quality of the advanced model is not satisfying. We prefer to use the simple model in routine clinical practice since it is more user-friendly than the CT-based model.

EP-1733 CFR-PEEK vs titanium spinal stabilization implants in photon and proton therapy: A phantom study

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Purpose or Objective

High density implants cause artefacts in CT and MRI which is problematic for the delineation process and dose calculation. The high density titanium implants are not properly accounted for in the dose calculation algorithms of the treatment planning system (TPS). This can result in an incorrect computation of the dose on TPS. Implants made from carbon fiber reinforced polyetheretherketone (CFR-PEEK) are radiolucent, non-magnetic and have a low density. Therefore, they do not produce artefacts and should be more compatible with the TPS algorithms. This study aims to assess the advantages of CFR PEEK vs. titanium implants in both photon and pencil beam scanning proton therapy (PT) for spinal treatment.

Material and Methods

A unique phantom was developed with 4 interchangeable inserts at spine level Th 7-11: one **reference** case with a native spine and three with a spinal stabilization implant consisting of: **titanium**, **CFR-PEEK** and a **hybrid** composition of both materials. These 4 scenarios were irradiated with both proton and photon plans with a fraction dose of 2 Gy. A single field and a clinical scenario with 3 fields Intensity Modulated PT (IMPT) plan with spinal cord sparing were applied with protons. Static field plans and VMAT plans were created with the Varian Eclipse planning system and applied with a Varian linac with 6 MV photons. The severity of the artefacts was measured by size, contouring time and overlap with other structures. The delivered dose was measured with GafChromic films.

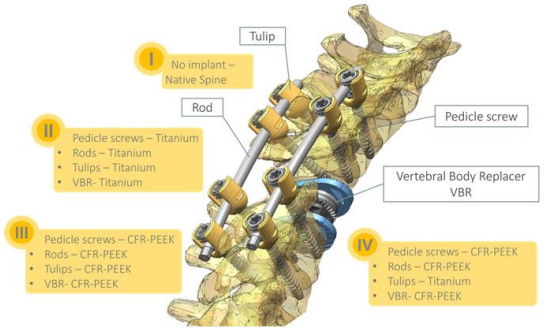

Figure 1: *Design schematic of the interchangeable insert of the phantom. The 4 different inserts exist of: A native spine (case I), a full titanium implant (case II), an implant completely out of CFR-PEEK (case III) and a hybrid implant where the tulips are made of titanium (case IV).*

Results

The total volume of artefacts on CT was 390.6 cc, 174.2 cc and 33.9 cc for the titanium, hybrid and CFR-PEEK case respectively; with 7.5% of the spinal cord and 58.2% of the GTV affected by artefacts for the titanium while these structures were not affected in the CFR-PEEK cases. This resulted in a delineation time 4 times shorter for CFR-PEEK case (43.7 ± 36.5 min) compared to the titanium case (172.0 ± 111.6 min). The single field proton plans showed a large deviation of measured dose in the titanium containing cases. In the clinical plans this improved slightly, but cold spots still exceeded clinical acceptance levels of >5%. Photon plans showed the same effect for a single dorsal static field. The disturbance by titanium results in hot and cold spots with dose deviations up to 25% of the prescribed dose. The applied VMAT plans showed no detectable dose deviations compared to the reference case. The CFR-PEEK showed in all plans a result comparable to reference. The maximum deviation measured by GafChromic films with respect to the prescribed dose for all cases an both planning techniques are presented in Table I.

	Protons		Photons	
	Single field	*3 field SC sparing*	*single field*	*VMAT SC sparing*
Reference	4.4%	4.6%	5.5%	10.0%
Titanium	14%	10.8%	25.0%	10.0%
CFR-PEEK	4.0%	4.7%	7.0%	10.0%
Hybrid	17.5%	13.5%	11%	10.0%

Table 1: *Represented is the maximum relative deviation of the prescribed dose as measured with the GafChromic films for the different plans. The single field plans and the 3 field and VMAT plan with spinal cord (SC) sparing for proton and photons respectively. Results of all the 4 phantom cases implant are presented.*

Conclusion

Whereas titanium leads to severe artefacts, prolonged planning time and incorrect dose calculations, use of CFR-PEEK implants solved all these issues. As such, CFR-PEEK implants should be used during the surgical procedure if adjuvant PT is considered for a patient.

EP-1734 Dosimetric effects due to uncertainties in tissue segmentation for prostate cancer treatments

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Purpose or Objective

In a previous work, presence of gold markers, contrast in the bladder and rectum interpretation were identified as potential factors influencing tissue segmentation and causing discrepancies between dose distributions from the TPS and a Monte Carlo (MC) system [Phys Med 51 (2018) 32]. Thus, the objective of this work is to quantify dosimetric effects on the target dose determination due to uncertainties in tissue segmentation for prostate cancer treatments.

Material and Methods

CT scans of more than 200 consecutive VMAT plans for prostate cancer were reviewed. Three groups of plans were selected: (i) 18 plans with enhanced CT artifacts in the PTV due to presence of gold markers but no contrast in the bladder or visible air in the rectum as a part of the PTV; (ii) 15 plans with contrast in the bladder as a part of the PTV but no marker artifacts or air in the rectum in the PTV; (iii) 15 plans with air in the rectum as a part of the PTV but no contrast in the bladder in the PTV. Calculations were carried out by Eclipse™ TPS algorithms, AAA and Acuros XB (dose to medium (AXB_m)) and by an MC system (dose to water/medium (MC_w)/(MC_m)) based on the EGSnrc. Dose distributions were obtained on the original CT scans as well as on the modified scans by setting HU to zero in the PTV, the bladder and the rectum for groups (i), (ii) and (iii), correspondingly. DVH estimates such as the mean dose to the CTV, PTV, $D_{98\%}$ PTV and $D_{2\%}$PTV were compared to evaluate the effect of the various factors.

Results

The parameter $D_{98\%}$PTV was most sensitive to uncertainties in tissue segmentation, notably gold markers and air in the rectum. The maximum difference between AAA and MC_w was 2.8% (i) and 5.4% (ii) and between AXB_m and MC_m 1.1% (i) and 4.5% (ii) (Figure 1). The variations were reduced to ± 2.1% when $D_{98\%}$PTV was determined on modified scans with HU=0 in the PTV or the rectum. A more detailed investigation showed that the TPS dose domination may be distributed in larger parts of the PTV volume with markers and visible CT artefacts (Figure 2). For group (ii), AAA may dominate locally, in the air part of the PTV, whereas the dose to the rest of the PTV may be lower compared to MC_w. In the case of contrast in the bladder, all DVH parameters showed similar results for calculations on original and modified CT scans. The median difference between AAA, AXB_m, MC_w and MC_m estimations of the mean dose to the CTV and the PTV was within 0.5% for all cases. Mean dose deviations up to 2.4% were observed for individual plans.

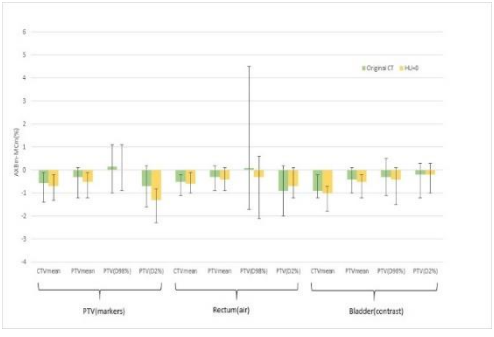

Figure 1. The median difference between DVH parameters estimated by AXB_m and MC_m for the three groups. Green bars – original scans, yellow bars – modified scans. Error bars; min-max variation of the difference.

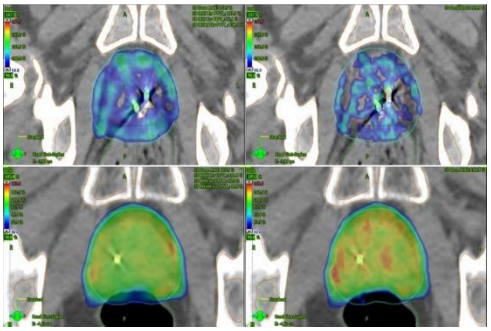

Figure 2. Dose distributions for selected plans from (i) and (ii). Color scale starts with 98%.

Conclusion

The presence of gold markers and inclusion of rectum air in the PTV may increase the variations in the $D_{98\%}$PTV estimation. However, no clinically relevant dosimetric effects were detected.

EP-1735 Dosimetric verification of single isocenter VMAT for multiple brain metastases

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Purpose or Objective

To verify the dose delivered by a single isocenter volumetric modulated arc therapy (VMAT) for stereotactic radiosurgery (SRS) of multiple brain metastases.

Material and Methods

Verification measurements were performed on single isocenter SRS plans of patients with 4-10 brain metastases treated on a Varian TrueBeamSTx. The 3x8Gy plans, calculated with Varian Eclipse treatment planning system (TPS) (Acuros version 15.5.11, 1mm grid size), consisted of 2 coplanar arcs and were normalized to deliver 100 % of the prescription dose to all lesions.

Firstly, the dosimetric agreement between radiochromic EBT-XD film and the calculation by the TPS was investigated. Films were placed in an Alderson radiation therapy head phantom (ART-200) in 2 transverse planes both intersecting high dose regions. The phantom was positioned using a CBCT and 6 degrees of freedom (6D) couch. The film dosimetry measurement was analysed by Film QA pro software (Ashland) using the one-scan method with a dose threshold of 50% and a local gamma criterion of 2%, 2mm[1].

Secondly, to check the consistency of the film measurement, portal dose measurements were done by acquiring MV pre-treatment greyscale value images per field using a Varian aS1000 flat panel and converting them to full-scatter portal dose images using the dosimetric calibration model described in [2]. These measured portal dose images were converted to fluence and reconstructed to a 3D dose distribution in the CT data set. The evaluation was performed using a gamma criterion of 3%, 3mm.

Results

Comparison between film and calculation show a mean agreement of 96.3% for both measurement planes for all plans with 4-10 brain lesions. The gamma analysis of the reconstructed 3D dose distribution resulting from the portal dose measurements shows a mean agreement score of 99.7%.

Conclusion

We have found that both film as well as portal dose based dosimetry show comparable agreements with TPS